HYDROGEN AND ITS COMPOUNDS

4.0 INTRODUCTION :

Hydrogen is the lightest element and also the lightest gas in the periodic table.

Order of Abundance of H :

Hydrogen is the most abundant element in the universe (70% of the total mass of the universe.)

Order of abundance of H : Universe > Sun > Earth

The planets Jupiter & Saturn consist mainly of H_2. Similarly about half the mass of the sun & some other stars is made up of hydrogen.

In Sun's atmosphere & in universe, it is found in atomic form. While in earth it is generally found in molecular form. At Sun, the stratosphere is made up of H (atomic hydrogen) & they undergoes fusion & converted into He nuclei & this reaction is exothermic.

It is the ninth element on earth in order of abundance.

Earth does not posses enough gravitational force to retain live hydrogen molecule i.e. why it is not found in earth atmosphere in atomic form.

Hydrogen is the most reactive element in atomic form but it is less reactive in molecular form because of very high bond dissociation energy due to 1s -1s overlapping.

4.1 ISOTOPIC EFFECT :

The effect which can change the physical & chemical properties of isotopes is called isotopic effect.

It is because of difference in mass.

In isotopic effect maximum changes occurs in physical properties like melting point, boiling point, bond energy, while minimum changes occurs in chemical properties like state of chemical reaction etc.

Imp. Isotopic effect is found only in hydrogen isotopes. Because there is a large difference in mass.

Ex. Which of the following reaction is fast & why ?

(i) $CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$

(ii) $CD_4 + Cl_2 \longrightarrow CD_3Cl + DCl$

Ans. (i) because C–H bond energy is less in comparison to C–D bond energy.

4.2 METHOD OF PREPARATION :

(a) From acids :

The metal which are placed above H_2 in electrochemical series react with dil acids to liberate H_2.

e.g. $Fe + \underset{\text{(dil)}}{H_2SO_4} \rightarrow FeSO_4 + H_2$

$Cu + H_2SO_4 \rightarrow \times$(No reaction)

Lab preparation : When impure Zn reacts with dil H_2SO_4 it forms H_2

$$\underset{\text{(impure)}}{Zn} + \underset{\text{(dil)}}{H_2SO_4} \rightarrow ZnSO_4 + H_2$$

Ex. Why we use impure Zn.

Ans. Because the rate of reaction with pure Zn is very slow.

(b) By alkalies : Only (Be, Zn, Al, Sn, Pb, Si) (Amphoteric metal) react with boiling NaOH or KOH to evolve H_2.

$$Zn + 2NaOH \rightarrow \underset{\text{(sodium zincate)}}{Na_2ZnO_2} + H_2\uparrow$$

$$2Al + 2NaOH + 2H_2O \longrightarrow \underset{\text{(sodium meta aluminate)}}{2NaAlO_2} + 3H_2\uparrow$$

$$Sn + 2NaOH + H_2O \longrightarrow \underset{\text{(sodium stannate)}}{Na_2SnO_3} + 2H_2\uparrow$$

$$Pb + 2NaOH + H_2O \longrightarrow \underset{\text{(sodium plumbate)}}{Na_2PbO_3} + 2H_2\uparrow$$

$$Si + 2NaOH + H_2O \longrightarrow \underset{\text{(sodium silicate)}}{Na_2SiO_3} + 2H_2\uparrow$$

$$Be + 2NaOH \longrightarrow \underset{\text{(sodium beryllate)}}{Na_2BeO_2} + H_2$$

(c) With water :

(i) With cold water (7°C-25°C) : Li, K, Ba, Ca, Na, Sr

(ii) With hot water (25°C-90°C) : Mg, Al, Cr, Mn, Zn

(iii) With steam (greater then 100°C) : Fe, Cd, Ni, Sn, Pb

(d) Commercial or industrial method to prepare H_2 :

The commonly used processes are outlined below:

(i) Electrolysis of acidified water using platinum electrodes gives hydrogen.

$$2H_2O(l) \xrightarrow[\text{Traces of acid/base}]{\text{Electrolysis}} 2H_2(g) + O_2(g)$$

(ii) High purity (>99.95%) dihydrogen is obtained by electrolysing warm aqueous barium hydroxide solution between nickel electrodes.

(iii) It is obtained as a by product in the manufacture of sodium hydroxide and chlorine by the electrolysis of brine solution. During electrolysis, the reactions that take place are:

at anode: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

at cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

overall reaction : $2Na^+(aq) + 2Cl^-(aq) + 2H_2O(l) \rightarrow Cl_2(g) + H_2(g) + 2Na^+(aq) + 2OH^-(aq)$

(iv) **From hydrocarbons :** Reaction of steam on hydrocarbons or coke at high temperatures in the presence of catalyst yields hydrogen.

$$C_nH_{2n+2} + nH_2O \xrightarrow[Ni]{1270K} nCO + (3n+1)\,H_2$$

e.g., $CH_4(g) + H_2O(g) \xrightarrow[Ni]{1270K} CO(g) + 3H_2(g)$

The mixture of CO and H_2 is called *water gas*. As this mixture of CO and H_2 is used for the synthesis of methanol and a number of hydrocarbons, it is also called *synthesis gas or* **'syngas'**. Nowadays 'syngas' is produced from sewage, saw-dust, scrap wood, newspapers etc.

The process of producing 'syngas' from coal is called *'coal gasification'*.

(v) **Bosch process :**

$$C(s) + H_2O(g) \xrightarrow{1270K} CO(g) + H_2(g)$$

The production of dihydrogen can be increased by reacting carbon monoxide of syngas mixtures with steam in the presence of iron chromate as catalyst.

$$CO(g) + H_2O(g) \xrightarrow[\text{catalyst}]{673K} CO_2(g) + H_2(g)$$

This is called *water-gas shift reaction*.

(vi) **Lane's process :**

$$\underset{\text{steam}}{Fe + H_2O} \longrightarrow Fe_3O_4 + H_2\uparrow$$

4.3 PHYSICAL PROPERTIES OF HYDROGEN :

(i) Hydrogen is the lightest, colorless, odourless and tasteless gas. It is sparingly soluble in water. It is inflammable and less reactive gas.

(ii) Its m.p. (– 259.2^{0}C) and b.p. (–252^{0}C) are very low indicating less intermolecular attraction. Due to low m.p. liquid hydrogen is used as a **cryogenic fluid** (to produce low temperature).

(iii) H—H bond energy [104 Kcal mol^{-1}] and 436 KJ/m

(iv) H – H bond length [74 pm] so H_2 is less reactive and require high temp for reaction.

4.4 USES OF HYDROGEN :

1. Hydrogenation of vegetable oil to form solid fats i.e. vanaspati ghee.
2. In liquid form as a rocket fuel. (Liquid H_2 + Liquid O_2)
3. In a air ship of balloons as a mixture of Hydrogen & Helium [15% H_2 + 85% He]
4. Formation of different compounds.

   Like → NH_3, (Haber process) alkane, alcohol and other hydrocarbons

BEGINNER'S BOX–1

1. Hydrogen does not combine with
(1) Antimony (2) Sodium (3) Bismuth (4) Helium

2. Which of the following produces hydrolith with dihydrogen
(1) Mg (2) Al (3) Cu (4) Ca

3. Hydrogen combines with other elements by
(1) Losing an electron (2) Gaining an electron
(3) Sharing an electron (4) Losing, gaining or sharing electron

4. Hydrogen acts as a reducing agent and thus resembles
(1) Halogen (2) Noble gas (3) Radioactive elements (4) Alkali metals

5. Hydrogen readily combines with non-metals and thus it shows its
(1) Electronegativity character (2) Electropositive character
(3) Both (1) and (2) (4) None of these

6. The oxidation states shown by hydrogen are
(1) –1 only (2) Zero only (3) +1, –1, 0 (4) +1 only

7. Hydrogen readily combines with metals and thus shows its
(1) Electropositive character (2) Electronegative character
(3) Both (1) and (2) (4) None of these

8. In which of the compounds does hydrogen have an oxidation state of –1
(1) CH_4 (2) NH_3 (3) *HCl* (4) CaH_2

9. Match List I (Fuels) with List II (composition) and select the correct answer using the codes given below the lists

List I (Fuels)	**List II (Composition)**
A. Water gas	i. A mixture of CO and N_2
B. Producer gas	ii. Methane
C. Coal gas	iii. A mixture of CO and H_2
D. Natural gas	iv. A mixture of CO, H_2, CH_4 and CO_2

	A	B	C	D
(1)	iii	i	iv	ii
(2)	iii	i	ii	iv
(3)	i	iii	iv	ii
(4)	iii	ii	iv	i

4.5 HYDRIDES

The binary compounds of hydrogen with different elements are called hydrides.

These are of three types :

(a) Ionic/Salt like/Saline hydrides :

- Compounds of hydrogen with s-block elements except beryllium & magnesium are called ionic hydrides.

  LiH, NaH, KH, RbH, CsH, CaH_2, SrH_2, BaH_2

  BeH_2, MgH_2 are covalent polymeric hydride.
- Structure of these hydrides are similar to rock salt, so they are also called salt like/saline hydrides.
- Down the group, atomic size↑ Lattice energy↓ stability↓ Melting point↓ Boiling point↓
- On electrolysis of these hydrides, hydrogen is liberated at anode.
- On reaction with water these hydrides will form hydrogen

  $NaH + H_2O \longrightarrow NaOH + H_2$
- These hydrides form complex hydrides which are very good reducing agents.

  $4LiH + AlCl_3 \longrightarrow LiAlH_4 + 3LiCl$

  $LiAlH_4 \longrightarrow$ Lithium aluminium hydride

  $NaBH_4 \longrightarrow$ Sodium borohydride

(b) Metallic / Interstitial hydrides :

- They are the compounds of d & f-block elements. In these hydrides hydrogen occupies interstitial sites present in metallic lattice, so they are called interstitial hydrides.
- Properties of these hydrides are similar to parent metals, so they are also known as metallic hydrides.
- These hydrides are non stoichiometric in nature (i.e. having variable composition)

  ZrH_x (x = 1.3 – 1.75)

  TiH_x (x = 1.8 – 2)
- Metals of group 7,8,9 don't form any hydrides so this particular part of periodic table is known as hydride gap.
- In group-6 only one hydride CrH is formed.

(c) Covalent/Molecular hydrides

- They are the compounds of hydrogen with p-block elements CH_4, NH_3, H_2O, HF, etc.
- These hydrides exist as molecules, so they are also known as molecular hydrides. There hydrides are non-conductor of electricity.

These hydrides are again divides into 3 categories.

(a) Electron deficient hydrides :

They are the hydrides of group 13 elements.

e.g. BH_3, AlH_3, GaH_3 – In these hydrides central element does not have complete octet. i.e. why they are called electron deficient compounds.

(b) Electron precise hydrides :

They are the hydrides of group 14 element.

e.g. CH_4, SiH_4, GeH_4 – In these type of hydrides central element has $8e^-$ in its outer most shell.

(c) Electron rich hydrides :

These are the hydrides of group 15, 16 and 17

e.g. $\ddot{N}H_3$, $H_2\ddot{O}$, $H\ddot{F}:$ – In these hydrides lone pair are present on central element which can be given to others. So they are called electron rich hydrides.

4.6 HARD AND SOFT WATER

Water which produces lather with soap is **soft water** while water which does not produces lather with soap is **hard water**. The hardness of water is caused by presence of bicarbonates, chlorides and sulphates of calcium and magnesium.

$$Ca^{2+}(aq) + 2C_{17}H_{35}COO^{-}(aq) \longrightarrow (C_{17}H_{35}COO)_2Ca \downarrow$$

$$Mg^{2+}(aq) + 2\underset{\text{Anion of soap}}{C_{17}H_{35}COO^{-}}(aq) \longrightarrow \underset{\text{Insoluble precipitates}}{(C_{17}H_{35}COO)_2Mg} \downarrow$$

Hardness of water are of two types :

(a) Temporary hardness (b) Permanent hardness

(a) **Temporary hardness :** This is due to the presence of bicarbonates of calcium and magnesium.

Temporary hardness in water is easily removed by boiling, as the bicarbonates decompose readily and the insoluble compounds are precipitated.

$$Ca(HCO_3)_2 \xrightarrow{\text{Boiling}} \underset{\text{(Insoluble)}}{CaCO_3} + H_2O + CO_2$$

$$Mg(HCO_3)_2 \xrightarrow{\text{Boiling}} \underset{\text{(insoluble)}}{Mg(OH)_2} + 2CO_2$$

Temporary hardness can also be removed by **Clark's process** which involves the addition of slaked lime [$Ca(OH)_2$].

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow \underset{\text{(Insoluble)}}{2CaCO_3} + 2H_2O$$

It is essential to add only the calculated amount of $Ca(OH)_2$ because excess will cause artificial hardness.

(b) **Permanent hardness :** This is due to the presence of sulphates or chlorides of both of calcium and magnesium. This type of hardness cannot be removed by boiling or by the addition of slaked lime.

The various water softeners are :

(i) **Washing soda :** It removes both the temporary and permanent hardness by converting soluble calcium and magnesium compounds into insoluble compounds.

$$CaCl_2 + Na_2CO_3 \longrightarrow \underset{\text{(Insoluble)}}{CaCO_3} + 2NaCl$$

$$CaSO_4 + Na_2CO_3 \longrightarrow \underset{\text{(Insoluble)}}{CaCO_3} + Na_2SO_4$$

$$Ca(HCO_3)_2 + Na_2CO_3 \longrightarrow \underset{\text{(Insoluble)}}{CaCO_3} + \underset{\text{(Soluble)}}{2NaHCO_3}$$

In place of sodium carbonate, caustic soda or sodium phosphate can also be used.

$$MgCl_2 + 2NaOH \longrightarrow \underset{\text{(Insoluble)}}{Mg(OH)_2} + 2NaCl$$

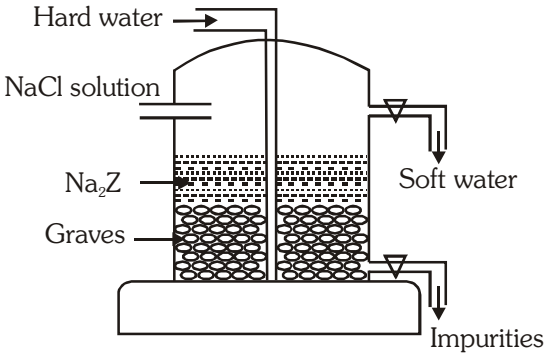
$$3MgSO_4 + 2Na_3PO_4 \longrightarrow \underset{\text{(Insoluble)}}{Mg_3(PO_4)_2} + 3Na_2SO_4$$

(ii) **Calgon :** The complex salt of metaphosphoric acid, sodium hexametaphosphate $(NaPO_3)_6$, is known as **calgon.** It is represented as $Na_2[Na_4(PO_3)_6]$. Calcium and magnesium salts present in hard water react with calgon to give complex salts.

$$2CaSO_4 + Na_2[Na_4(PO_3)_6] \longrightarrow Na_2[Ca_2(PO_3)_6] + 2Na_2SO_4$$

$$2MgSO_4 + Na_2[Na_4(PO_3)_6] \longrightarrow Na_2[Mg_2(PO_3)_6] + 2Na_2SO_4$$

(iii) **Permutit process :** Permutit is hydrated sodium alumino silicate $[Na_2Al_2Si_2O_8.\ xH_2O]$ or $[Na_2O.Al_2O_3.2SiO_2.xH_2O]$



Permutit is also known as sodium zeolite (Na_2Z) means Zeolite is $Al_2Si_2O_8.xH_2O$.

In this process when hard water is poured into chamber, it may contain organic impurities like plant. These impurities can be removed by gravel.

On moving upwards hard water will react with Na_2Z during this reaction Na^+ ions of Na_2Z will replace Mg^{+2} & Ca^{+2} of impurities.

$$Na_2Z + CaCl_2 \longrightarrow 2NaCl + CaZ$$

NaCl is dissolved in water & water becomes soft.

This soft water is fit for washing purpose but not fit for drinking purpose.

After some time when Na_2Z is completely converted into CaZ. Process is stopped and for regeneration of Na_2Z. We use NaCl solution.

$$2NaCl + CaZ \longrightarrow CaCl_2 + Na_2Z$$

(iv) **Ion exchange resin :** This process removes both temporary and permanent hardness. Also, by this process we can remove both cation & anion of hardness.

This process contain two chambers.

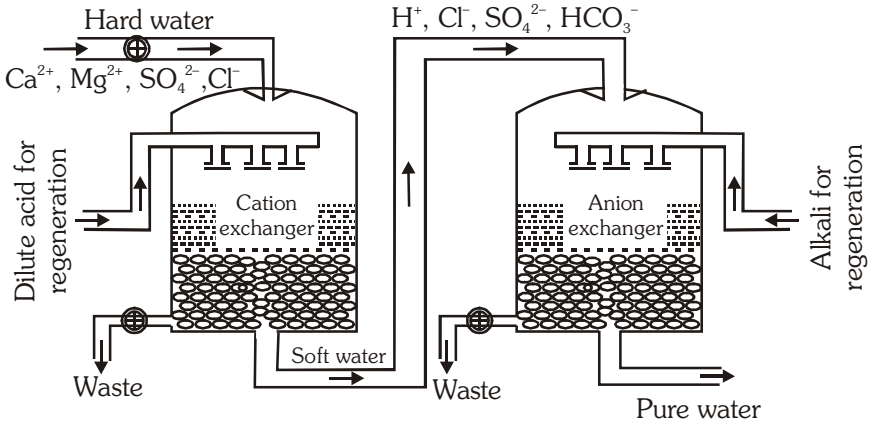
(a) Cation exchange resin : This resin contains granular insoluble organic acid having giant molecules with $RCOO^-H^+$ group.

(b) Anion exchange resin : This resin contain giant organic molecules with basic groups derived from amines with $RNH_3^+OH^-$

Process : When hard water is poured into first chamber the cation of hardness (Mg^{+2}. Ca^{+2}) removed by H^+ ions of organic acid.

$$2RCOO^-H^+ + CaCl_2 \longrightarrow (RCOO)_2Ca + 2H^+ + 2Cl^-$$

$$2RCOO^-H^+ + MgSO_4 \longrightarrow (RCOO)_2Mg + 2H^+ + SO_4^{-2}$$



This water becomes soften but not used for drinking purpose because this water contain the impurity of acid. To remove anion of hardness this acidic water then passed through another bed containing anion exchanger. This exchanger removes anion like Cl^-, SO_4^{-2} & HCO_3^-.

$$RNH_3^+OH^- + H^+ + Cl^- \longrightarrow RNH_3^+Cl^- + H^+OH$$

This water is free from impurities & can be used for drinking purpose.

After sometime when both resin gets exhausted process is stopped.

Regeneration of resin :

(i) Cation exchange resin : We use dil acid.

$$2H^+Cl^- + (RCOO)_2Ca \longrightarrow 2RCOO^-H^+ + CaCl_2$$

(ii) Anion exchange resin : We use dil NaOH solution

$$RNH_3^+Cl^- + Na^+OH^- \longrightarrow Na^+Cl^- + RNH_3^+OH^-$$

4.7 HEAVY WATER (D_2O)

Method of preparation :

Repeated electrolysis of H_2O : On electrolysis of water (impure) H_2O dissociate into H^+ & OH^- while a fractional part of D_2O will dissociate into D^+ & OD^-

$$H_2O \rightleftharpoons H^+ + OH^-$$

$$D_2O \rightleftharpoons D^+ + OD^-$$

D^+ & OD^- due to more mass have less mobility i.e. why H^+ & OH^- will move towards cathode & anode respectively while D^+ & OD^- will be in solution.

This process is repeated six times.

Properties of Heavy water :

Physical properties :

(a) Heavy water is a colourless, odourless and tasteless mobile liquid.

(b) Nearly all the physical constants are higher than the corresponding values of ordinary water.

(dielectric constant order $H_2O > D_2O$).

Chemical properties :

(a) Heavy water is chemically similar to ordinary water. However, D_2O reacts more slowly than H_2O in chemical reactions.

(b) All chemical properties are same, but reactions are slow.

Uses : As a neutron moderator : Fission in uranium-235 is brought by slow speed neutrons. The substances which are used for slowing down the speed of neutrons are called moderators. Heavy water is used for this purpose in nuclear reactors.

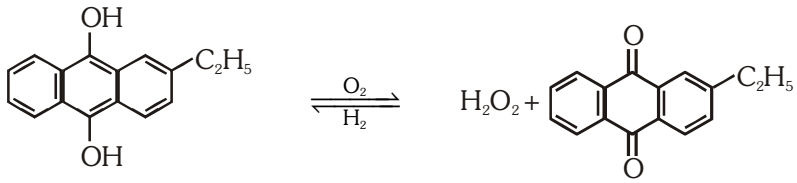
4.8 H_2O_2 (HYDROGEN PEROXIDE)

Method of preparation

(i) Acidifying barium peroxide and removing excess water by evaporation under reduced pressure gives hydrogen peroxide.

$$BaO_2.8H_2O(s) + H_2SO_4 \rightarrow BaSO_4(s) + H_2O_2(aq) + 8H_2O(\ell)$$

(ii) Industrial Method : Auto oxidation of 2 ethyl anthraquinol (cyclic process) :



(iii) Electrolytic Process : (Used 50%) H_2SO_4 in electrolytic cell using Pt as anode and graphite as cathode.

$$2H_2SO_4 \longrightarrow 2H^+ + 2HSO_4^{\ominus}$$

At Cathode $2H^+ + 2e^- \longrightarrow H_2\uparrow$

At Anode $2HSO_4^- \longrightarrow H_2S_2O_8 + 2e^-$

(Peroxo disulphuric acid) ;

$H_2S_2O_8 + H_2O \longrightarrow H_2SO_4 + H_2SO_5$ [Peroxo monosulphuric acid (Caro's acid)]

$H_2SO_5 + H_2O \longrightarrow H_2SO_4 + H_2O_2$

Physical properties :

(i) Pure H_2O_2 is colourless, odourless liquid and impure with bluish layer.

(ii) It has more Hydrogen bonding then H_2O. So, order of boiling point is $H_2O_2 > D_2O > H_2O$

$$\text{Order of melting point} = \left[\underset{-0.35°C}{H_2O_2} < \underset{0°C}{H_2O}\right]$$

(iii) It is soluble in H_2O, alcohol and ether.

(iv) It has bitter taste and harmful for skin.

(v) It is a dibasic weak acid.

(vi) It has oxidising as well as reducing property.

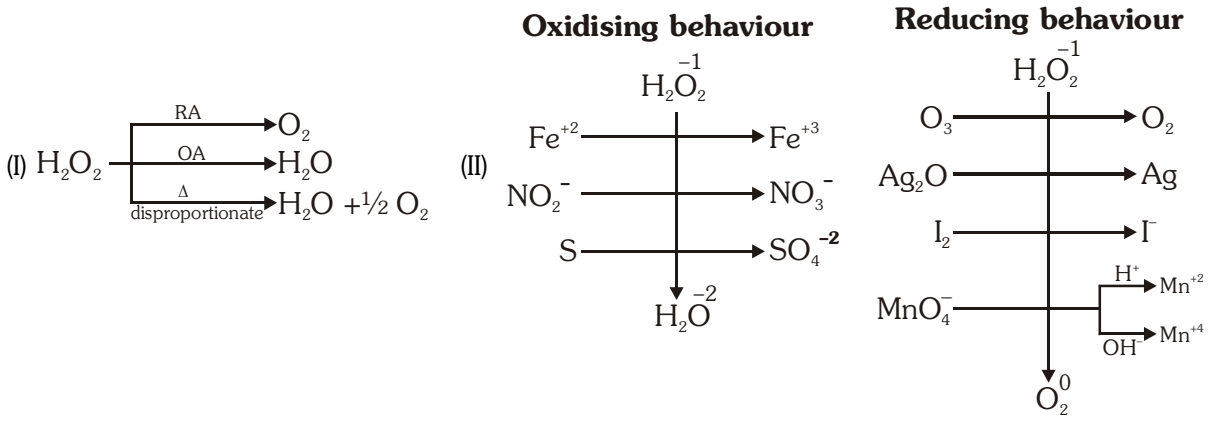
(vii) H_2O_2 easily decompose in presence of light and temperature, so H_2O_2 always kept in dark bottles and kept at cool places & small amount of inhibitor is added like R–OH, glycerol & Acetone.

(viii) 30% solution of H_2O_2 is called **Perhydrol**.

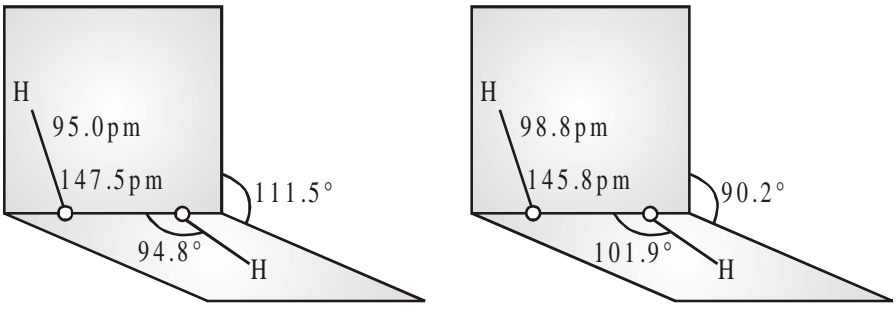
(ix) H_2O_2 decomposes at its boiling point hence its distillation is carried out under reduced pressure.

Chemical properties :

(A) Oxidising and Reducing behaviour of H_2O_2



Structure of hydrogen peroxide



(a) Gas phase (a) Solid phase

Uses

(i) Bleaching agent (ii) Hair dying

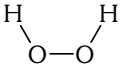
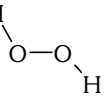
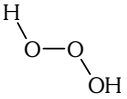
(iii) $H_2O_2 + N_2H_4$ as Rocket propellent (iv) H_2O_2 as oxidant and reductant

(v) Antiseptic

BEGINNER'S BOX–2

1. Among the following, identify the compound which cannot act as both oxidising and reducing agents
(1) H_2O_2 (2) H_2 (3) SO_2 (4) HCl

2. In which of the following reaction hydrogen peroxide is a reducing agent
(1) $2FeCl_2 + 2HCl + H_2O_2 \longrightarrow 2FeCl_3 + 2H_2O$ (2) $Cl_2 + H_2O_2 \longrightarrow 2HCl + O_2$
(3) $2HI + H_2O_2 \longrightarrow 2H_2O + I_2$ (4) $H_2SO_3 + H_2O_2 \longrightarrow H_2SO_4 + H_2O$

3. The structure of H_2O_2 is
(1)  (2)  (3)H–O–O–H (4) 

4. The oxide that gives hydrogen peroxide on the treatment with a dilute acid is
(1) MnO_2 (2) PbO_2 (3) Na_2O_2 (4)TiO_2

5. Temporary hardness may be removed from water by adding
(1)$CaCO_3$ (2)$Ca(OH)_2$ (3)$CaSO_4$ (4) HCl

6. Temporary hardness of water can be removed by
(1) Addition of potassium permanganate (2) Boiling
(3) Filtration (4) Addition of chlorine

7. When zeolite (Hydrated sodium aluminium silicate) is treated with hard water the sodium ions are exchanged with
(1)OH^- ions (2) SO_4^{2-}ions (3) Ca^{2+} ions (4) H^+ions

8. The velocity of neutrons in nuclear reactor is slowed down by
(1) Heavy water (2) Ordinary water (3) Zinc rod (4) Fused caustic soda

9. When temporary hard water containing $Mg(HCO_3)_2$ is boiled the ppt. formed is of
(1) $MgCO_3$ (2) MgO (3)$Mg(OH)_2$ (4) None of these

10. Which of the following can effectively remove all types of hardness of water
(1) Soap (2) Washing soda (3) Slaked lime (4) None of these

ANSWER KEY

BEGINNER'S BOX-1	Que.	1	2	3	4	5	6	7	8	9	
	Ans.	**4**	**4**	**4**	**4**	**2**	**3**	**2**	**4**	**1**	

BEGINNER'S BOX-2	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	**4**	**2**	**2**	**3**	**2**	**2**	**3**	**1**	**3**	**2**

EXERCISE-I (Conceptual Questions)

BASED ON HYDROGEN

1. Out of the following metals which will give H_2 on reaction with NaOH :
I : Zn, II : Mg,
III : Al, IV : Be
(1) I, II, III, IV (2) I, III, IV
(3) II, IV (4) I, III

2. The gas used in the hydrogenation of oils, in presence of nickel as a catalyst is :
(1) methane (2) ethane
(3) ozone (4) hydrogen

3. Hydrogen has the tendency to loose one e^- and form H^+, In this respect it resembles with :
(1) Alkali metal (2) Carbon
(3) Alkaline earth metal (4) Halogens

4. H_2 gas can not be prepared by :-
(1) Be + NaOH (2) Na + NaOH
(3) Mg + NaOH (4) By (2 & 3) method

5. Deuterium, an isotope of hydrogen is :-
(1) Radioactive (2) Non radioactive
(3) Heaviest (4) Lightest

6. Hydride gap in periodic table is from :-
(1) Group 7 to group 9
(2) Group 5 to group 7
(3) Group 4 to group 6
(4) Group 7 to group 10

7. Which of the following reaction is called water gas shift reaction ?
(1) $C(s) + H_2O(g) \longrightarrow CO(g) + H_2(g)$
(2) $3Fe(s) + 4H_2O(steam) \longrightarrow Fe_3O_4 + 4H_2(g)$
(3) $CH_4(g) + H_2O(g) \xrightarrow[1270\,K]{Ni} CO(g) + 3H_2(g)$
(4) $CO(g) + H_2O(g) \xrightarrow[FeCrO_4]{773\,K} CO_2(g) + 3H_2(g)$

BASED ON WATER

8. Which is true statement about D_2O and H_2O :-
(1) D_2O has lower dielectric constant than H_2O
(2) NaCl is more soluble in D_2O than in H_2O
(3) both are correct
(4) none is correct

9. The reactions of heavy water are slow
The reason is :-
(1) Heavy water is associated
(2) Heavy water is dissociated
(3) High bond energy of D–O bond
(4) Heavy water is of lower mass

10. Hard water when passed through ion exchange resin containing RCOOH group, becomes free from :-
(1) Cl^- (2) SO_4^{-2}
(3) H_3O^+ (4) Ca^{+2}

11. Permutit is a technical name given to :-
(1) Aluminates of Ca and Na
(2) Hydrated silicates of Al and Na
(3) Silicates of Ca and Na
(4) Silicates of Ca and Mg

12. The formula of sodium zeolite which is used in permutit process for softening water is :-
(1) $Na_2O.Al_2O_3.Si_2O_4.xH_2O$
(2) $Na_2.Al_2.Si_2O_4.xH_2O$
(3) $Na_2O.AlO_3.SiO_4.xH_2O$
(4) $K_2Al_2SiO_8.xH_2O$.

13. The compound sodium hexameta phosphate $Na_2[Na_4(PO_3)_6]$ is called calgon because :-
(1) It was developed by the scientist
(2) It was developed first in California
(3) It refers to calcium gone
(4) It is based on the name of the company which developed it.

14. Permanent hardness in water due to presence of :-
(1) Ca^+, Mg^+ (2) $CaCl_2$, $MgCl_2$
(3) $CaCO_3$, $MgCO_3$ (4) All

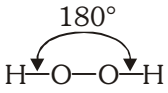
15. Temporary unstable hardness of water due to presence of :-
(1) $CaCl_2$, $MgSO_4$
(2) Ca^{+2}, Mg^{+2}
(3) K^+ , $CaCO_3$
(4) $Ca(HCO_3)_2$, $Mg(HCO_3)_2$

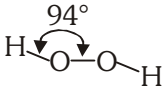
16. In which of the following method of the removal of hardness, Ca^{+2} and Mg^{2+} are not separated from sample of hard water ?
(1) By boiling of temporary hard water
(2) Addition of sodium carbonate
(3) Using sodium hexa meta phosphate
(4) Synethetic resins and zeolite method

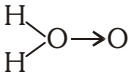
BASED ON HYDROGEN PEROXIDE

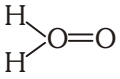
17. H_2O_2 is used but not as :-
(1) oxidant, reductant (2) bleaching agent
(3) antiseptic (4) catalyst

18. Which of the following is a true structure of H_2O_2:-

(1) 

(2) 

(3) 

(4) 

19. In the reaction $2H_2O_2 \rightarrow 2H_2O + O_2$, oxidation state of oxygen changes as :-
(1) Only – 1 to –2
(2) Only – 1 to zero
(3) Both of the above
(4) –1 to –3

20. The dipole moment of H_2O_2 is 2.1D. This indicates that the structure of H_2O_2 is :-
(1) Linear (2) Non-linear
(3) Symmetrical (4) None

21. Bleaching action of H_2O_2 is due to its :-
(1) Oxidising nature
(2) Reducing nature
(3) Acidic nature
(4) Thermal instability

22. Correct order of boiling point is :-
(1) $H_2 > H_2O_2 > D_2O > H_2O > D_2$
(2) $H_2O_2 > H_2 > D_2O > H_2O > D_2$
(3) $H_2O_2 > D_2O > H_2O > D_2 > H_2$
(4) $H_2O_2 > D_2O > H_2O > H_2 > D_2$

23. $H_2O < H_2O_2$ order is incorrect for :-
(1) Boiling point (2) Acidic nature
(3) Dipole moment (4) Strength of H-bond

EXERCISE-I (Conceptual Questions) ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	**2**	**4**	**1**	**4**	**2**	**1**	**4**	**1**	**3**	**4**	**2**	**1**	**3**	**2**	**4**
Que.	16	17	18	19	20	21	22	23							
Ans.	**3**	**4**	**2**	**3**	**2**	**1**	**3**	**4**							

Directions for Assertion & Reason questions

These questions consist of two statements each, printed as Assertion and Reason. While answering these Questions you are required to choose any one of the following four responses.

(A) If both Assertion & Reason are True & the Reason is a correct explanation of the Assertion.

(B) If both Assertion & Reason are True but Reason is not a correct explanation of the Assertion.

(C) If Assertion is True but the Reason is False.

(D) If both Assertion & Reason are false.

1. ***Assertion :*** Decomposition of H_2O_2 is a disproportionation reaction.
Reason : H_2O_2 molecule simultaneously undergoes both oxidation and reduction.
(1) A (2) B (3) C (4) D

2. ***Assertion :*** The colour of old lead paintings can be restored by washing with dilute solution of H_2O_2.
Reason : Black lead sulphide is oxidised by H_2O_2 to white lead sulphate
(1) A (2) B (3) C (4) D

3. ***Assertion :*** The O–O bond length in H_2O_2 is shorter than that in O_2F_2.
Reason : H_2O_2 is ionic compound
(1) A (2) B (3) C (4) D

4. ***Assertion :*** Hard Water is not fit for washing clothes.
Reason : It contains Ca^{+2} & Mg^{+2} ion which can forms ppt with soap.
(1) A (2) B (3) C (4) D

5. ***Assertion :*** Rate of reaction
$CD_4 + Cl_2 \rightarrow$ Slow ; $CH_4 + Cl_2 \rightarrow$ Fast
Reason : Due to isotopic effect.
(1) A (2) B (3) C (4) D

6. ***Assertion :–*** Saline hydrides are non volatile, non conducting & crystalline solids.
Reason : Saline hydrides are compounds of hydrogen with most of the p-block elements.
(1) A (2) B (3) C (4) D

EXERCISE-II(Assertion & Reason) ANSWER KEY

Que.	1	2	3	4	5	6
Ans.	**1**	**1**	**4**	**1**	**1**	**3**